

# **The Next-Generation A/G Communications System**

## **MNS-137**

## Mission Needs Statement (MNS)

### EXECUTIVE SUMMARY

The Federal Aviation Administration (FAA) needs air/ground (A/G) communications to provide safety-critical Air Traffic Control (ATC) services. Specific needs documented in this MNS include the following:

- Provide Air Traffic (AT) controllers the capability to accommodate the growing number of sectors and services using the available, limited radio frequency (RF) spectrum.
- Reduce logistical costs (supplies, maintenance, training, etc.), i.e., replace expensive to maintain VHF and UHF radios that are of the 1940s technology and have exceeded their life expectancy by 10 years.
- Provide new data link communications capability to all classes of users.
- Reduce A/G RF interference and provide security mechanisms to identify unauthorized users (e.g., "phantom controllers").

#### Current Capability and Infrastructure

VHF and UHF radio A/G communication links are needed to support all phases of flight: from the coordination of ground movements on the airport surface, including gate areas, to the coordination of departures and arrivals in the terminal area, to the coordination needed to support the en route phase of flight. In addition, A/G communications link is also needed to provide flight services (Automated Flight Service Stations, AFSSs). Functionally, the need for A/G communications includes requirements to ensure aircraft separation, to transmit instructions and clearances, for hand-offs, and to provide weather services and pilot reports (PIREPs). Air traffic safety is highly dependent upon A/G communication capability.

The A/G radio communication infrastructure is comprised of approximately 54,000 radios (VHF and UHF transmitters, receivers, and transceivers) installed at over 2,500 remote transmitter/receiver (RTR), remote center A/G communications facilities (RCAG) and remote communications outlets (RCO) radio sites in the United States. The infrastructure provides air traffic communications capabilities for en route, terminal and flight service operational environments.

#### Deficiencies

##### A/G Communications System Capacity

Demand for access to A/G communication frequency assignments (channels) is generally proportional to the level of air traffic which has grown steadily. Since the last significant increase in the number of channels in 1972 (through the reduction from 50 kHz to 25 kHz channel spacing), air traffic has nearly doubled. The demand for A/G frequency assignments is expected to increase four percent annually between FY 1992 and FY 2002. This growth, together with the evolution of new services to aircraft, such as broadcast and transmission of new

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weather services, will create a demand for A/G communications that will be extremely difficult to satisfy in all U.S. high density areas.

### A/G Communications Infrastructure Support

The FAA Logistics Center (FAALC) analyzed the mean time between failure (MTBF) for the ITT-made A/G radiounits in order to plan for their rate of replacements. The results of the analysis depicts a significant decrease in MTBF for expendable and exchange and repair (E&R) items for each year beginning with FY89 through FY94.

### Other Deficiencies

In addition to the above capacity and infrastructure problems, other important deficiencies have been documented with the current system. They are:

- No data link capability;
- Susceptibility to radio frequency interference;
- No security against unauthorized users;
- Channel blockage ("stuck microphone").

### Planned Capability

The planned capability is to provide a next-generation A/G communications system to satisfy the current and identified future functional requirements that cannot be met using the current voice communications system. The capabilities of the planned system would include the following:

- Ensure the available radio frequency (RF) spectrum can meet efficient utilization for voice and data requirements;
- Reduce susceptibility to radio frequency interference (RFI);
- Improve communications systems security;
- Support remote maintenance monitoring;
- Reduce user workload;
- Provide consistent voice quality over a range of operating conditions.

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### Proposed Alternatives

Presented in this MNS there are three basic VHF alternatives, each with and without UHF replacement. The base year for communications capacity was taken to be 1994. A constant growth rate of four percent per year was assumed for the VHF frequency demand and 1.5 percent increase per year for UHF frequencies. Growth in UHF demand is assumed to be satisfied with additional equipment, rather than changes in mode of operation. The three basic VHF alternatives are summarized as follows:

- Alternative No. 1, Improve Current System Spectrum Efficiency Using Current 25 kHz Radio Standards;
- Alternative No. 2, New Radio Based on Frequency Division Multiplexing (FDM); providing voice-only capability
- Alternative No. 3, New Radio Based on TDMA 25 kHz; providing voice and data capabilities.

### Recommendation

Recommend that:

- This MNS be approved
- The Phase 1 Proposal and Exit Criteria be approved to evaluate the alternatives identified above in order to assess their qualities and relative merits, and to perform a cost-benefit analysis.

### Impact of Disapproving the Acquisition

- Channels will not be available to meet future requirements for ATC sectors;
- Operating cost of obsolete equipment will continue to increase;
- New requirements for integrated voice and data will not be satisfied;
- Transition to future A/G communication system will be difficult.

### **1. ADMINISTRATIVE INFORMATION**

- a. Title: The Next-Generation A/G Communications System
  - b. MNS Number: 137
- c. Submission Date: 10/05/94

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### 2. DESCRIPTION OF THE MISSION NEED:

The Federal Aviation Administration (FAA) needs air/ground (A/G) communications to provide Air Traffic Control (ATC) services. VHF and UHF radio A/G communication links are needed to support all phases of flight: from the coordination of ground movements on the airport surface, including gate areas, to the coordination of departures and arrivals in the terminal area, to the coordination needed to support the en route phase of flight. In addition, A/G communications link is also needed to provide flight services (Automated Flight Service Stations, AFSSs). Functionally, the need for A/G communications includes requirements to ensure aircraft separation, to transmit instructions and clearances, for hand-offs, and to provide weather services and pilot reports (PIREPs).

The current mode of communications is primarily voice but in the future, data link communications will be provided as well. This Mission Need Statement (MNS) addresses the need for new A/G radios to replace aging, expensive to maintain equipment in a system which does not have the capacity to meet the current and near-term ATC communication demands.

Specific needs documented in this MNS include the following:

- Provide Air Traffic (AT) controllers the capability to accommodate the growing number of sectors and services using the available, limited radio frequency (RF) spectrum.
- Reduce logistical costs (supplies, maintenance, training, etc.), i.e., replace expensive to maintain VHF and UHF radios that are of the 1940s technology and have exceeded their life expectancy by 10 years.
- Provide new data link communications capability to all classes of users.
- Reduce A/G RF interference and provide security mechanisms to identify unauthorized users (e.g., "phantom controllers").

Since the 1940s, the increase in the air traffic demand has been met by increasing the VHF system's spectrum-limited capacity through "channel splitting" or decreasing the separation between frequency assignments. As the spacing has decreased from 200 kilohertz (kHz) to 100 kHz, to 50 kHz, and to the present 25 kHz, the problems caused by co-siting and intermodulation have increased, limiting the effective capacity of the system. Capacity problems are most evident in congested air traffic regions. Demand for A/G communications is greater, due to the increased number of aircraft and sectors. Spectrum capacity for new frequency assignments in these congested areas is limited by the influence of the many preexisting frequency assignments in the area.

Finally, the issue of whether or not future air traffic control of military aircraft will be performed by utilization of current UHF communications or the future VHF A/G communications system must be studied jointly with DOD. Results of such a study would determine mission need requirements for UHF communications equipment for FAA control of military aircraft.

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### a. Statutory or Regulatory Authority and High Level directives:

The statutory and regulatory authority for this mission need is contained in the Congressional Federal Aviation Act of 1958 (as amended), FAA Executive Policy Statements, FAA Strategic Plan, FAA orders, and other documents.

The Federal Aviation Act of 1958 requires the Administrator to provide necessary facilities for the regulation and protection of air traffic. A key element for accomplishing this mission is the transfer of information (voice and data) between ground and aircraft [1].

The Aeronautical Mobile (Route) Service (AM(R)S) regulatory requirements, providing air traffic services (ATS) and Aeronautical Operational Control (AOC) communications, are contained in the following:

- Federal Aviation Regulation (FAR);
- The International Telecommunications Union (ITU) spectrum allocations and Radio Regulations;
- FCC rules and regulations;
- National Airspace System (NAS) System Requirements; and
- International Civil Aviation Organization (ICAO) Standard and Recommended Practices (SARPs).

The U.S. ATS and AOC service rules for the use of the 117.975-137 MHz Aeronautical Mobile Route Service (AM(R)S) are contained in the U.S. 47 Code of Federal Regulations (CFR), Part 87, Aviation Services. General Operating and Flight rules are contained in parts 91, 121, 125, 127, and 135 of the FAR.

It should be noted that ATC is the primary interface between the FAA and users of the nation's airspace and comprises many distinct services. The primary ATC service is the communications of safety-critical ATC instructions including passage of requests, instructions, and advisory reports between pilots and air traffic controllers and specialists via A/G radios [2].

The next-generation A/G communications system must satisfy current voice requirements and be consistent with stated FAA strategic plans and goals including the following:

- Meet future voice and data link spectrum capacity and performance requirements;
- Improve telecommunications cost-effectiveness of ATS operation (air traffic control and flight information services);
- Support FAA conversion to a predominately digital system;
- Support implementation of an integrated communications architecture.

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The goals must be accomplished while maintaining safety. Because the A/G communication is used for real-time control of the aircraft, it must be able to support ATC operational functions and be available on a continuous basis.

### b. Functional Requirements

The FAA's A/G radio communications system must:

- Provide sufficient spectrum capacity in the VHF A/G communications band;
- Reduce/avoid increases in operational and maintenance (O&M) funding requirements associated with the currently aging A/G radios;
- Reduce susceptibility to RF interference and increase security of communications of the system;
- Provide simultaneous voice and data link capability to satisfy ATS requirements;
- Meet system operational performance availability for voice and data; and
- Provide additional features to satisfy the A/G communication requirements identified by the FAA in conjunction with RTCA, Inc. and ICAO.

The critical nature of the information and services provided by the A/G communications system requires that the system be operational on a continuous basis. Service to all users must remain uninterrupted during the transition to any new system. This requirement may effectively increase the demand for A/G frequency assignments during transition since old and new system will operate simultaneously during the transition period.

The functional capabilities required to provide ATS for all users, including general aviation (GA), are contained in the RTCA Working Group 1 Report (September 1994), and are included in Appendix B to this Mission Need Statement.

### 3. RATIONALE FOR THE ACQUISITION:

#### a. Current Capability

##### (1) Description:

The current ATS A/G radio system is based on a design that was formulated in the 1940s. The system consists of voice-based networks that use double-sideband amplitude modulation (DSBAM) radios and operates in the 117.975-137 MHz band for civil aircraft and the 225-400 MHz band for military aircraft. For the VHF band, this provides a total of 760 assignable 25 kHz channels, of which just over 500 are available for ATC use in the U.S. The remaining channels are used for other (non-ATC) aeronautical purposes. The radios operate in a simplex "push-to-talk" fashion, with the same frequency used for uplink

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(controller-to-pilot) and downlink (pilot-to-controller) transmissions. As the volume of air traffic has risen, so have the number of frequency assignments (approximately 10,000) for voice channels in the continental U.S., including metropolitan areas with high A/G communications traffic.

The A/G radio communication infrastructure includes approximately 54,000 radios (VHF and UHF transmitters, receivers, and transceivers) installed at over 2,500 remote transmitter/receiver (RTR), remote center A/G communications facilities (RCAG) and remote communications outlets (RCO) radio sites in the United States. The infrastructure provides air traffic communications capabilities for en route, terminal and flight service operational environments. The A/G systems associated with each environment (and their corresponding control facilities, e.g., ARTCCs and AFSS) are not interconnected. For example, two FAA radio facilities may be close to each other (similar coverage), but belong to different ARTCCs. Because of the fixed-tune, hard-wired radios, the sites usually cannot back each other up even though they both may be able to receive the signal from the same aircraft.

Installation of radios that form the kernel of the A/G communications infrastructure began in 1969. The median age of the radios and ancillary equipment (e.g., antennas, cables, and racks) currently exceeds the expected life cycle of 15 years. The equipment (manufactured by ITT) that was originally purchased is no longer available. The FAA is procuring VHF/UHF radios which are equivalent to ITT radios (manufactured by Motorola) to satisfy a limited expansion of the current A/G system. Additional information on the capability to maintain this equipment is included in Appendix D.

### (2) Deficiencies:

#### A/G Communications System Capacity

Demand for access to A/G communication channels is generally proportional to the level of air traffic which has grown steadily. An average rate of six percent growth in air traffic has been maintained in the 1977-1992 period, and the last significant increase in the number of channels was made in 1972 through the introduction of 25 kHz channel spacing. During these 15 years air traffic has nearly doubled. The demand for A/G frequency assignments is expected to increase four percent annually between 1992 and 2002. The evolution of new services, such as broadcast and transmission of new weather services, further contribute to the growth in the demand for A/G communications. As stated in the FAA Telecommunications Strategic Plan [1], the future A/G communications system must evolve to accommodate growth in demand for air traffic services.

In recent years, it has become increasingly difficult to engineer frequencies for the new A/G channels in certain U.S. metropolitan areas. This problem of VHF A/G spectrum depletion in the U.S. national airspace has been analyzed in two recent studies.

In 1992 the FAA performed a study of VHF A/G frequency requirements [3], with emphasis on the congested region around JFK airport in New York. The key findings of that study were:

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- Over the 18-year period from 1974 to 1992, the total number of U.S. frequency assignments to VHF A/G channels had more than doubled, with an average annual growth rate of four percent for the period.
- In 1992 there were 809 existing VHF A/G frequency assignments, using a total of 378 distinct frequencies in the portions of the 117.975-136 MHz band then available for this purpose, in the circular region within 200 nautical miles (nmi) of JFK.
- By 1992 the spectrum at JFK was already too saturated to be able to accommodate more than four additional local control channels without violating FAA frequency-assignment criteria.
- By 1992 the spectrum at JFK was already too saturated to add any new high-altitude channels, with 200 nmi radii, at JFK or at selected locations 200 nmi north, west, and south of JFK without violating FAA frequency-assignment criteria.
- Even if the radii of the new high-altitude circuits were reduced to 100 nmi, none could be accommodated at the airport, and only two to six could be added at any of the three selected locations 200 nmi away.
- Between 1997 and 2002, within 200 nmi of JFK it will be very difficult to make new VHF frequency assignments, especially for high-altitude service.

In 1993, a more extensive study of VHF A/G spectrum depletion in the U.S. national airspace was commissioned by the FAA Office of Spectrum Policy and Management . This analysis considered six key metropolitan areas: New York City, Chicago, Atlanta, Dallas, Denver, and Los Angeles. For each of the six areas, the analysis quantified existing spectrum occupancy and remaining spectrum resources. Table 1 summarizes the results of the study.

- The Air/Ground Assignments column in Table 1 shows how many of the channels existing in 1992 operated at least partially within a 30-nmi radius of the nominal center of each metropolitan area.
- The next column, Frequencies Still Usable for Future Terminal Service, shows how many of the hypothetical new terminal channels could be assigned interference-free frequencies in each of the areas.
- The last column shows how many of the hypothetical en route channels could be engineered.

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**TABLE 1 VHF A/G SPECTRUM UTILIZATION**

Metropolitan Area	Air/Ground Assignments in 1992	Frequencies Still Usable for Future Terminal Service (1)	Frequencies Still Usable for Future En Route Service (1)
New York City	198	28	0
Chicago	155	34	0
Atlanta	109	29	0
Dallas	176	69	0
Denver	176	108	24
Los Angeles	287	35	3

(1) NOTE: Potential cosite interference problems are ignored here (see text). The actual number of usable frequencies at any radio site may be considerably less due to cosite interference.

It is important to note that the "terminal" and "en route" results were generated in separate analysis and hence are independent of one another.

It is evident from this study that it will be extremely difficult to engineer additional frequency assignments for long-range (200-nmi), high-altitude (45,000-foot) en route channels in the New York, Chicago, Atlanta, Dallas, and Los Angeles metropolitan areas. Of the six areas studied, only the Denver area still has an adequate supply of frequencies usable for future en route service requirements.

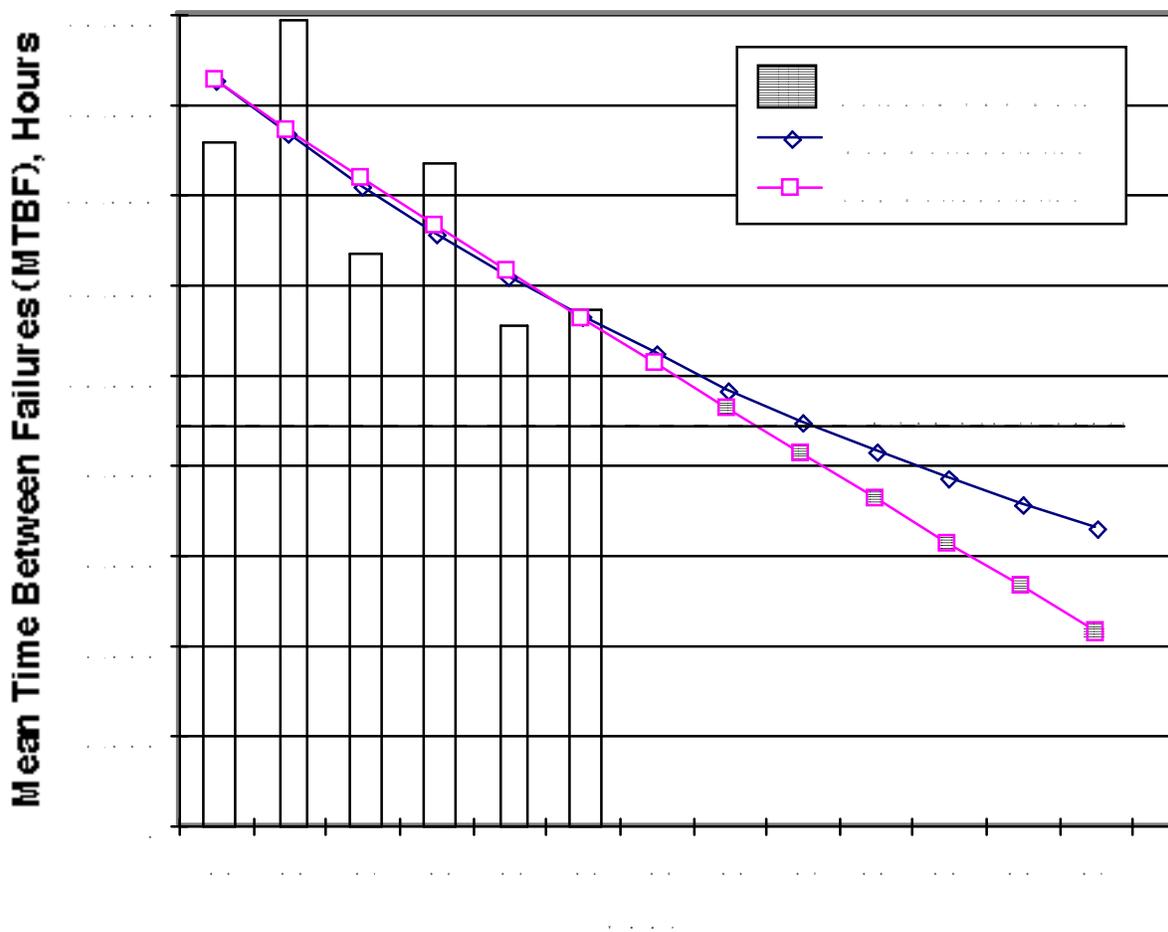
It is not expected that a large amount of future requirements for assignments will be for en route services having large service volumes. Conversely, it is foreseen that future requirements for terminal area assignments will continue at the current rate of about 4 percent per year. All six of the areas are still able to accommodate additional "terminal" channels with 30-nmi service volume radii and 10,000-foot altitudes. However, if no changes are made to the existing system architecture and if channel requirements continue to grow even at a relatively modest annual rate of 2 percent, severe shortages may develop for terminal service as well. It is projected to be impossible by the year 2000 (or sooner) to engineer additional frequency assignments for new terminal channels in the New York City and Los Angeles areas, and similar shortages are likely to develop in other metropolitan areas soon thereafter. Only a limited improvement in voice capacity could be expected by the use of the new channels in the portion of the 136-137 MHz band available for ATS; in any case, this would require new radios for the user community.

### A/G Communications Infrastructure Support

The FAA Logistics Center (FAALC) analyzed the mean time between failure (MTBF) for the ITT units in order to plan for their rate of replacements. The results of the analysis, summarized in Table 2 and Figure 1, depicts a significant decrease in MTBF for expendable and exchange and repair (E&R) items for each year beginning with FY89.

**TABLE 2 Recent Mean Time Between Failures (MTBF) Rate for ITT Radios**

Year	Items Issued	MTBF, hrs
FY89	24,223	15,189
FY90	20,552	17,902
FY91	28,901	12,730
FY92	25,008	14,712
FY93	33,101	11,115
FY94 (projected)	32,057	11,477



**Figure 1 MTBF Rate for ITT Radios**

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Since there is no FAA-wide system that captures records of all radio failures to estimate future MTBF, the FAALC assumed a constant number of 42,000 ITT radios operating continuously for 24 hours a day for a year, or 42,000 unit-years of operation. Dividing the 42,000 by 32,057 issued items, the estimated MTBF for FY94 results in 1.3 years per radio, or 11,477 hours. As a comparison, current technology radios have an estimated MTBF of 40,000 hours (one failure every 4.6 years). Considering the FY89-FY94 experience, FY93 and FY94 may be the beginning of a significant trend toward more failures. Simple extrapolations of the FAALC data indicates sharply decreasing MTBF. The FAALC expects to provide support for the ITT units within reasonable costs for the next five years.

### No Data Link Capability

Because the current analog A/G communications system does not provide data link services, the FAA leases such services in order to provide Pre-Departure Clearances (PDC) at thirty airports. This data link is based on 20-year old analog data link technology that is very outdated and spectrally inefficient. The leased service operates within the U.S. AOC spectrum allotment of the VHF band (117.975 - 137 MHz) where there is already a severe shortage of assignable frequency channels for dispatch communications with the aircraft. Furthermore, this data link does not include a suitable message priority structure nor operate at a sufficient speed to meet the ATS data link message timeliness requirements specified in NAS-SR-1000 [4].

The Future Air Navigation System (FANS) CNS/ATM plan calls for ATS to operate via VHF data link, reserving voice for emergency and non-routine communications. The same 117.975 -137 MHz band segment that currently provides voice must also, therefore, be utilized to provide a data link capability as additional spectrum can not be attained internationally for this function. Users are requesting early availability of numerous digital data link applications based on their successful experience with analog data links [5].

The current voice-only system is susceptible to problems such as misstated or misinterpreted verbal messages, which create confusion and ambiguity about frequency assignments and other messages. This results in higher controller and pilot workload.

### Susceptibility to Radio Frequency Interference

Current A/G communications are disrupted by ever increasing forms of Radio Frequency Interference (RFI). This causes a safety hazard to operators within and outside of affected sectors. Also, operations are impacted as air traffic specialists are forced to change sector communications to alternate frequencies (if available) during outages.

Amplitude modulation (AM) is particularly susceptible to many forms of interference, such as that from plastic welding equipment, frequency modulation (FM) broadcast station intermodulation products, malfunctioning communications transmitters, power lines, broadband noise, and portable electronic devices. The effects of interference range from nuisance squelch breaks during the absence of pilot-controller communications to levels of interference that entirely block the use of the RF channel. FAA Airways Facilities (AF) personnel are tasked to resolve the increasing number of field interference cases

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using highly technical mobile test equipment. In 1992, FAA Spectrum Engineering personnel expended approximately 1,200 staff-days to resolve cases of RFI, with many additional staff hours utilized in support of RFI investigations by field personnel. As the RF spectrum becomes more crowded with users of new systems, it is expected that interference to AM channels will continue to increase.

### No Security Mechanism to Guard Against Unauthorized Users

Unauthorized users, including "phantom controllers" who emulate air traffic control specialist instructions, intentionally transmit in an unauthorized manner on assigned ATC communications frequencies. In 1992 alone there were 37 documented cases of unauthorized users. In 1994, the most significant case reported by the media was the phantom controller in the Roanoke area.

FAA AF staff is tasked to resolve cases of unauthorized use of ATC channels and participate in interagency teams comprised of FAA, FBI and FCC personnel to resolve such cases, using sophisticated test and location equipment. The proliferation of accessible communications equipment dictates that mechanisms be introduced to provide increased levels of security into the VHF communications system to protect against this problem. This severe safety hazard cannot be easily overcome by using the present analog system, whereas, security mechanisms are generally available using digital systems.

### Other Deficiencies

Channel blockage occurs when multiple users transmit simultaneously or when a radio is inadvertently keyed for sustained period. This latter situation is referred to as a "stuck microphone" and results in complete loss of a channel, thus blocking communications with all aircraft in the associated sector and compromising safety.

With the current system, proper A/G connectivity is accomplished by manual radio tuning performed by the pilot. When a new frequency is to be assigned, it is verbally provided to the pilot. A misstatement or misinterpretation of the frequency assigned can result in total loss of communications. Correction of the problem further increases workload for the controller, pilot or both.

User addressing is verbal through the use of the flight's call sign (a flight identifier for airline flights or registration number for general aviation). Continuous pilot monitoring is required to identify transmissions directed to the cockpit. Any lapse in monitoring and miscommunication with wrong aircraft results in the controller making repeated call attempts, increasing controller workload.

### **b. Planned Capability:**

The planned capability is to provide a next-generation A/G communications system to satisfy the current and identified future functional requirements that cannot be met using the current voice communications system. The capabilities of the planned system would include the following:

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- Efficient radio frequency spectrum utilization to meet voice and data requirements;
- Reduced susceptibility to RFI;
- Improved communications systems security;
- Remote maintenance monitoring for A/G system elements;
- Reduced user workload;
- Consistent voice quality over a range of operating conditions.

### c. Proposed Alternatives:

The alternatives presented in this MNS were developed considering the background, context, and assumptions outlined in Appendices B and C. Among the factors considered are the satisfaction of ATS and AOC functional requirements and system transition capability requirements, plus the degree to which alternatives satisfy defined system improvement objectives.

From the perspective of communications system capacity improvement, factors such as spectrum engineering aspects, modulation, multiplexing, and multiple access techniques were considered in exploring system improvement alternatives. These include (1) the basic information throughput potential of a radio frequency channel; (2) the realizable information throughput; (3) frequency reuse potential (which results from the frequency assignment criteria); and (4) transition issues.

Two broad classes of alternatives are presented, each related to a different approach for multiplexing. One of these (Alternative 2) is frequency division multiplexing (FDM) in which every current 25-kHz radio frequency channel would be subdivided into narrower channels, each capable of supporting a separate voice channel. The other scheme (Alternative 3) is Time Division Multiplexing (TDM), in which each radio frequency channel would continue to be 25 kHz wide but would be shared on a cyclical basis by multiple channels. In a TDM system, each of the channels sharing an radio frequency channel would have exclusive use of the channel during a short time slot forming part of a longer time interval known as a "frame."

#### Alternative 1: Improve Current System Spectrum Efficiency Using Current 25 kHz Radio Standards

This alternative replaces the current obsolete equipment with new equipment; however, it does not provide the needed spectrum capacity improvement. Alternative 1 is presented as a frame of reference because it only addresses replacing the current system with limited enhancements. In addition to not meeting the spectrum capacity requirements, it does not meet the new requirements identified in Appendix B including data link capability. However, Alternative 1 considers frequency management techniques and hardware changes thereby allowing for more (approximately 10 percent ) discrete frequencies within the given VHF band.

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### Alternative 2: New Radio Based on Frequency Division Multiplexing (FDM) for Voice-Only

This alternative achieves increased spectrum capacity through use of radios that utilize a narrow channel spacing (less than 25 kHz). The analog narrow channel spacing solution represents an extension of past radio standard changes. Analog systems have limited ability to support data transfer needed for enhanced features such as automatic channel management. Alternative 2 will provide more capacity (in the order of 2 to 3 times the current capacity). If an associated data link in the VHF spectrum band is implemented, additional spectrum and radio assets will be required

### Alternative 3: New Radio Based on Time Division Multiplexing (TDM) 25 kHz Voice and Data System

This alternative uses digital modulation and coding techniques to provide multiple voice and data "user channels" in a single 25 kHz frequency assignment. The time division multiple access alternative is based on the recognition that both voice and data link can be provided on the same radio frequency carrier. Alternative 3 will allow functionally simultaneous access to both, voice and data link, for aircraft equipped with a single antenna. It also provides a potential for a 25 kHz radio frequency channel "drop-in" replacement for the present 25 kHz frequency assignments. Thus, no additional radio frequency carriers at ground stations are required (i.e., no increase in cosite spectrum engineering constraints). Alternative 3, currently being defined in ICAO and RTCA, will provide more capacity (in the order of 4 times the current capacity) for the same number of frequency assignments as Alternative 1, with approximately the same number of radios as currently deployed.

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**Table 3 Summary of Alternatives**

<b>Alternative</b>	<b>Max. VHF Spectral Capacity</b>	<b>Capacity Used in Cost Estimates</b>	<b>Capabilities Not Covered</b>
<b>1A:</b> Improve Current System Spectrum Efficiency Using Current 25 kHz Radio Standards (25 kHz VHF)	1.1 times the current capacity	VHF: About 1.1 times the current capacity	Capacity requirements (for year 2002) Data link Future requirements UHF radios
<b>1B:</b> Improve Current System Spectrum Efficiency Using Current 25 kHz Radio Standards (25 kHz VHF and UHF)	1.1 times the current capacity	VHF: 1.1 times the current capacity  UHF: 1.05 times the current capacity	Capacity requirements (for year 2002) Data link Future requirements
<b>2A:</b> New Radios Based on Frequency Division Multiplexing (<25 kHz VHF)	2-3 times the current capacity	VHF: 1.5 times the current capacity  UHF: 1.16 times the current capacity	Future requirements RFI and security Data Link UHF radios
<b>2B:</b> New Radios Based on Frequency Division Multiplexing (<25 kHz VHF)  (Current 25 kHz UHF)	2-3 times the current capacity	VHF: 1.5 times the current capacity  UHF: 1.16 times the current capacity	Future requirements RFI and security Data Link
<b>3A:</b> New Radios Based on Time Division Multiplexing (VHF only)	4 times the current capacity	VHF: 1.5 times the current capacity	UHF radios
<b>3B:</b> New Radios Based on Time Division Multiplexing (VHF only)  (Current 25 kHz UHF)	4 times the current capacity	VHF: 1.5 times the current capacity  UHF: 1.16 times the current capacity	

#### **4. IMPACT OF DISAPPROVING THE ACQUISITION:**

##### **a. Safety**

Increasing numbers of cases of radio frequency interference, as described in section 3.a(2) of this MNS adversely impact the safety of the National Airspace System. During the periods when frequencies are affected, communications can be unheard or misinterpreted by airspace users posing a potential direct safety hazard to aircraft in flight, and adequate communications may not be available during transition to backup communications.

Unauthorized use of ATC channels as described in Section 3a(2) of this MNS poses the greatest safety impact to airspace users. Deliberate misinstructions by "phantom controllers" have caused aircraft to deviate from their controller assigned flight paths, causing a potential direct safety hazard to aircraft in flight.

If additional channels are not available to meet future requirements for ATC sectors, existing sectors will be required to serve an increasing number of aircraft in each sector. The cumulative safety impact of increasing the number of aircraft per sector without reducing controller workload in other ways must be considered by AT.

##### **b. Capacity**

The current system has reached its maximum spectrum capacity in many congested metropolitan areas and hubs and will be unable to meet the increase in operational or service demand resulting in increased system-imposed user delays. The current system will not be able to meet the new international standards, if adopted by ICAO. Even a modest growth rate prediction of four per cent per year in required channels, based upon historical data shows that the spectrum will be exhausted by 2002 in high traffic areas. As mentioned above, requirements for additional ATC sectors cannot be satisfied in the high traffic density region after this time. New data link services cannot be provided to aircraft in flight unless new capacity and capabilities are introduced.

##### **c. Cost**

The current system is obsolete and its operating cost is expected to increase with time as radio equipment continues to deteriorate.

Operating costs of the current system associated with RFI, security, and cosite implications are expected to increase due to current system susceptibility.

##### **d. Technical Support**

No program or contract for replacement of obsolete radios (GRR and GRT series) exists after 1997.

The Logistics Center has to "reengineer" components to support the vast majority of the A/G radios (GRR and GRT series).

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Difficulty and expense increase dramatically for transition if spectrum is saturated when beginning transition to new higher capacity system.

### 5. RESOURCE REQUIREMENTS

**Resource Requirements are not included in this version.**

### 6. RECOMMENDATIONS:

Recommend that:

- This MNS be approved,
- The Phase 1 Proposal and Exit Criteria be approved to evaluate the alternatives identified above in order to assess their qualities and relative merits, and to perform a cost-benefit analysis.

#### MNS Submission

\_\_\_\_\_  
Archie Archilla, AAF-1  
Director of Airways Facilities

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Date

\_\_\_\_\_  
Bill Jeffers, AAT-1  
Director of Air Traffic

\_\_\_\_\_  
Date

#### Mission Need Statement Approval

\_\_\_\_\_  
Dr. George Donohue, ARA-1  
Associate Administrator for Research and Acquisition

\_\_\_\_\_  
Date

\_\_\_\_\_  
TSARC Approval

\_\_\_\_\_  
Date

#### Designation As Performing Organization

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Performing Organization

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Date

**Appendix A**

**List of References**

1. Federal Aviation Administration, *National Airspace System Level 1 Design Document*, NAS-DD-1000E, August 1992, Washington, DC.
2. Federal Aviation Administration, *1994 Federal Aviation Administration Telecommunications Strategic Plan*, Washington, DC.
3. Sakai, G., Federal Aviation Administration, "Future Operational Impacts on VHF Air -Ground Communications Frequency Requirements in the United States Defined by a Study of JFK Airport," Working Paper presented at ICAO Aeronautical Mobile Communications Panel Meeting, Kobe, Japan, March 1992.
4. Federal Aviation Administration, *NAS System Requirements Specification*, NAS-SR-1000, November 1991, Washington, DC.
5. Federal Aviation Administration, *Draft System Plan for Aeronautical Data Link System*, 15 November 1994, Washington, DC.
6. VHF Air-Ground Communications System Improvements Alternatives Study and Selection of Proposal for Future Action, Document No. RTCA/DO-225, 17 November 1994.

## Appendix B

### Functional Capabilities Required and Desired Features [6]

#### 1. System Requirements

Article 51 of the ITU Rules and Regulations establishes an order of message priority for A/G communications to ensure that higher-priority safety communications messages will be transmitted before lower-priority safety communications or non-safety communications (if allowed in the band of interest). ICAO Annex 10, Volume I, Part II, Chapter 5, Section 5.1.8, establishes standards for message priority consistent with those of ITU Article 51.

A fundamental requirement is that any new VHF A/G communications system shall not cause a degradation in safety when compared with the existing VHF A/G communications system; however, there is an overall objective to improve safety.

The VHF A/G communications system design shall be capable of providing functionally simultaneous access to voice and data link communications.

The VHF A/G communications system design shall seek to minimize costs of the airborne radio units.

The ground infrastructure required for the future VHF A/G communications system shall be implementable on an incremental capacity/capability basis, at an acceptable cost and complexity. The VHF A/G communications system shall have worldwide applicability.

The future VHF A/G communications system design shall exhibit a simple human-machine interface for initiating and carrying out voice and data link communications. For voice communications, while other operational modes may be available, the future VHF A/G communications system shall be capable of emulating the basic push-to-talk (PTT) mode of the current system. User interfaces for data link communications shall be in accordance with the messages and message protocols specified in the RTCA DO-219 MOPS document for data link applications.

The future VHF A/G communications system shall support area coverage requirements, taking into account spectrum efficiency. Any new or improved VHF A/G communications system shall be capable of satisfying this requirement in an acceptable manner without increasing pilot or controller workload, or reducing the reliability of communications, all of which could have an impact on safety.

The VHF A/G communications system shall have the capability to provide service to several ATS volumes simultaneously within the VHF band.

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The VHF A/G communications system shall minimize circuit blockage due to the transmitter's being unintentionally keyed (usually referred to as the "stuck microphone" effect).

The VHF A/G communications system shall include the capability of supporting security measures to protect the system from unauthorized users (e.g., phantom controllers), for both voice and data link.

The VHF A/G communications system shall provide an increased degree of RFI protection relative to the present system.

The VHF A/G communications system shall have the capability to support automation of communications functions to reduce user workload and air crew "head-down" time.

The orderly transition process shall allow the present 25 kHz analog A/G communications system to be used or phased out, as required. The future VHF A/G communications system shall be capable of a phased introduction. Users must be capable of accessing the 25 kHz analog A/G communications system throughout the transition period to receive full ATS/AOC services.

If a mixed old and new VHF A/G communications system environment is used within a common group of users (e.g., an en route sector), the VHF A/G communications system shall be capable of supporting party line between the present voice VHF A/G communications system and any new voice system.

The future VHF A/G communications system shall support a technique to minimize the probability of simultaneous transmissions on a single A/G circuit.

The VHF A/G communications system shall have the capability of supporting automatic circuit management with manual override.

The VHF A/G communications system shall have the capability to address an individual and a selected group(s) of aircraft; acknowledgments would not necessarily be required.

The VHF A/G communications system shall be capable of supporting a service availability of 0.99999 for voice and 0.999 for data.

The VHF A/G communications system shall support a ground-to-air voice and data link broadcast capability.

The future VHF A/G communications system shall support a periodic link checking protocol between ground and airborne radios independent of actual user traffic. Additionally, upon detection of a link failure, automatic switching with manual override within the ground network and the airborne radio shall also be supported.

## 2. Voice Requirements

At a minimum, any new VHF A/G communications system shall be capable of providing the functional voice capabilities of the present 25 kHz analog A/G communications system, use the spectrum as

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efficiently as practical, and be capable of operating with no degradation in civil aviation system safety as compared with the present system.

In developing the future CNS concept, the ICAO FANS Committee considered that the future VHF A/G communications system would be largely data link-based, with voice reserved for emergency and non-routine functions. It is expected that voice communications will be relied upon for at least terminal ATC operations for the foreseeable future. Therefore, any new VHF A/G communications system must be capable of providing a voice capability.

The future VHF A/G communications system shall provide significantly greater voice capacity, at a minimum twice (the inherent system capacity) the A/G voice circuit capacity of the current system.

The VHF A/G communications system shall provide for a party line functional capability.

The VHF A/G communications system shall transparently support an air-to-air communications capability in addition to an A/G communications capability.

Voice communications shall be clearly intelligible and of acceptable quality from the user's perspective. The VHF A/G communications system shall have the capability to provide a dedicated A/G voice circuit for each air traffic controller or dispatcher, and his/her associated group of aircraft.

The end-to-end delay from audio into the transmitting station to audio out of the receiving station shall be less than 250 milliseconds (ms).

The VHF A/G communications system shall be capable of accepting audio without clipping after PTT activation.

Any future VHF A/G communications system shall not impose limitations or constraints on the total number of airborne users per talk group (i.e., sector), except when using discrete addressing. If services with discrete addressing are to be offered, the maximum number of users to receive these services on a given A/G circuit shall be a predetermined system design parameter. An address space that can accommodate at least 50 airborne users per circuit is required for discrete addressed services.

The VHF A/G communications system shall support entry of an aircraft into any talk group on demand.

The future VHF A/G communications system shall be capable of supporting emergency communications, as required. The system shall be compatible with the present 25 kHz analog A/G emergency communications system and with existing emergency locator transmitters (ELTs). The capability to monitor ELT transmissions shall be provided at ATC facilities such as Airport Traffic Control Towers (ATCTs), Automated Flight Service Stations (AFSSs), and Area Control Facilities (ACFs). The system shall provide receipt and transmission of emergency voice communications at AFSSs while maintaining voice communications via normal assigned circuits. The system shall have the capability to minimize the need to change circuits or frequencies when communicating with a user that has declared an emergency. The system shall be capable of supporting emergency communications requirements using 25 kHz DSB-AM voice on 121.5 MHz and 123.1 Mhz.

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The VHF A/G communications system shall support circuit access prioritization of voice messages.

### 3. Data Requirements

A data link communications capability shall be available for all users.

The future VHF A/G communications system shall support messages of various lengths, and shall provide a data link capability sufficient to deliver tactical ATS messages of 24 octets of application data within the delay constraints described below.

The VHF A/G communications system shall support prioritization of data link messages.

The probability that a message containing an undetected error will get to the end user shall be equal to or less than  $1 \times 10^{-8}$ , i.e., on average, 1 message with an error for every 100 million messages.

The future VHF A/G communications system shall be provided with error detection and correction capabilities; signal regeneration capabilities shall be provided as required.

Delivery of short tactical data link messages of 24 octets of application data or less shall be provided within 1 second with a probability of 0.95, and within 5 seconds with a probability of 0.999.

The VHF A/G communications data link subnetwork shall meet the requirements for ATN compatibility.

The system shall be capable of providing coverage over an area of any size using a single frequency.

### 4. Desired Features

In additions to the above requirements RTCA/AMCP have identified the following desirable features:

A digital system provides the capability to multiplex a number of voice and/or data link "A/G circuits" in a 25 kHz channel. Errors due to interference and noise can be minimized by error-correcting codes and interleaving. Recent advances in integrated circuit technology allow for economical implementation of digital systems.

The future VHF A/G communications system design should allow a single avionics unit to provide functionally simultaneous access to voice and data link communications in a cost-effective manner. A fundamental feature should be to allow the present DSB-AM voice and the new system capability to be provided in a single avionics unit.

A VHF A/G communications system design that provides for RF channel multiplexing and multiple accessing techniques capable of providing functionally simultaneous access to voice and data link communications on the same RF channel may be useful in fostering the participation of the general aviation (GA) minimum-capability users and other users with small aircraft (see Section 6.1.4). A single avionics unit and a single RF channel transmit and receive capability are consistent with the minimum VHF A/G communications capability of the present system.

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The future VHF A/G communications system should provide a call-queuing capability that gives an alert when a station is being called. The system should automatically indicate the order in which call requests were received. An acknowledgment should also be provided to verify to the pilot that the request has been received. Any priority scheme should be consistent with ICAO Annex 10, to the extent necessary. This capability would provide a solution for preventing "step-on," which is caused by simultaneous keying of transmitters on the same frequency.

Urgency messages should have an uplink override capability to pre-empt other communications on the voice channel. Also, urgency messages should have a downlink only capability which would allow a pilot to request urgent communications with the controller.

Appendix C

Synopsis of RTCA and ICAO Recommendations

1. Background

Western Europe voiced a need for action for a system change at the 1985 ICAO COM/OPS Divisional Meeting, stressing that the VHF AM(R)S band was becoming saturated. The international effort to study VHF A/G system improvements was agreed upon at the 1990 ICAO COM/MET/OPS Divisional Meeting, following the defeat of a European recommendation to adopt 12.5 kHz channel spacing. In a cooperative decision, it was recognized that action was needed to seek frequency congestion relief in Western Europe as soon as possible, resulting in the adoption of Recommendation 2/4 calling for a broad study of alternatives for future VHF A/G communications system improvements. Additionally, Recommendation 2/2 was adopted in order to develop ICAO SARPs for an ATN compatible VHF data link. Recommendations 2/4 and 2/2 are presented in Appendix C. These tasks were added to the work program of the ICAO AMCP.

The FAA was instrumental in establishing the RTCA SC-172 committee in 1991 to conduct a U.S. government and industry study in parallel with the ICAO activity. Working Group 1 was tasked to undertake a broad VHF A/G system improvements study, taking into account both near and long term improvements. Working Group 2 was tasked to develop Minimum Aviation System Performance Standards (MASPS), which would include characteristics compatible with ICAO SARPs to be developed in AMCP Working Group C.

2. **RTCA and ICAO Recommended Alternative**

In both the RTCA SC-172 and ICAO AMCP forums, a total of seven candidate future system alternatives were agreed upon and developed to the extent necessary to allow their comparative evaluation against the future system requirements. Each candidate system was capable of providing voice and data link communications. The seven candidates evolved after carefully taking into account that (1) these system architectures might have the potential to satisfy a broad range of future system requirements; (2) they represented a broad range of system designs, considering evolution from the present system and new technology/system designs; and (3) there was civil aviation interest in and support for pursuing their design. The seven alternative systems considered are as follows:

- 12.5 kHz DSB-AM Voice/25 kHz CSMA Data
- 8.33 kHz Voice/25 kHz CSMA Data
- 5 kHz AME Voice/25 kHz CSMA Data
- 5 kHz Digital Voice/25 kHz CSMA Data
- 5 kHz Digital Voice/5 kHz CSMA Data

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- 25 kHz TDMA (Voice/Data on Common RF Channel)
- 25 kHz DRMA (Voice/Data on Common RF Channel)

The selection of a future system candidate was based on evaluation of the capabilities of the seven system alternatives against the future system requirements. Highlighted and addressed were a number of discriminating issues that helped focus the selection of the future system candidate. A fully digital system, preferably with multiple circuits provided on the same RF channel, emerged as the optimum choice for meeting the future VHF A/G system requirements.

The TDMA architecture was considered to be consistent with the objectives that surfaced during the studies. Such a system design has the following features:

- Is based on mature technology.
- Is capable of satisfying foreseen system functional requirements.
- Offers a relatively high degree of increased communications capacity.
- Offers a significant degree of operational flexibility.
- Would support a wide range of growth paths.
- Potentially would allow a great degree of flexibility in system transitional implementation.

Note that the U.S. position on the 8.33 kHz alternative was described in the AMCP Working Paper "A North American Perspective on VHF Air-Ground System Improvements", which was cleared through IGIA. In summary:

- It considered in some detail why 8.33 kHz would not be capable of satisfying important U.S. FAA requirements (and it would not provide any new functional capability for the U.S. User Community): (1) no improvements in RFI immunity or security, (2) would require a sub-band for implementation, (3) increases cosite spectrum engineering constraints, and (4) would not allow a functionally simultaneous provision of voice and data link for small aircraft.
- This paper also stressed that a new VHF standard is needed as soon as possible in the U.S. to allow the standard to be included in a major new FAA ground radio procurement anticipated for the latter 1990s, and to give sufficiently advance notice to the U.S. User Community (on the order of 10 years for, in particular, general aviation) of the implementation of a new system standard.

The SC-172 Working Group 1 report, VHF Air-Ground Communications System Improvements Alternatives Study And Selection Of Proposals For Future Action, and the ICAO Report of Working Group B to the AMCP/3 studies have resulted in RTCA SC-172 and ICAO AMCP recommendations to pursue the development of the defined TDMA architecture for the VHF A/G communications system to

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satisfy identified future system requirements. Additionally, the September 1994 ICAO European Region Air Navigation Meeting (EUR/RAN) recommended that European States support the development of the defined TDMA architecture.

The ICAO VHF Digital Link (VDL) standards developed in RTCA SC-172 Working Group 2 and ICAO AMCP Working Group C can accommodate both the TDMA voice and data link architecture, as well as the CSMA data link only architecture (developed for AOC communications) in the same avionics unit. This is due to the agreement to use the same physical layer characteristics for both architectures, which resulted from very close coordination between the different working groups in RTCA and AMCP.

### **3. Future System Capabilities to Overcome Present System Shortcomings**

The TDMA architecture recommended by RTCA and ICAO will provide a significant increase in communications capacity (up to four times the current system capacity). This architecture will utilize not more than half of the total number of ground system radios required using the current system.

Additionally, this architecture supports full access to a high speed ATN compatible data link communications in a "functionally simultaneous" manner with voice communications. This enables all classes of aircraft users to obtain both services without interference.

The fully digital nature of this architecture allows for the introduction of security measures to enable pilots to authenticate ATC instructions.

This system supports operational improvements that enhance safety, such as an increased level of radio frequency immunity, discrete addressing, and a preemption capability for ATC to help overcome problems with channel blockage.

### **4. Recommendations from RTCA SC-172**

It is recommended that the FAA support the further development of the TDMA system design, in collaboration with other interested states, to bring the design to maturity in a timely manner, with the objective of requiring no interim solution.

It is recommended that RTCA SC-172 complete the specification of the TDMA system design, with the objective of the future development of MOPS. Consideration should be given to the ongoing work within ICAO, the FAA, and the VHF Data Radio Subcommittee of AEEC, with the objective of avoiding unnecessary duplication and/or conflict.

### **5. Recommendations from ICAO AMCP/3**

Development of a future VHF A/G communications system

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That ICAO endorse the timely standardization of a future VHF A/G communications system to meet the set of identified future system requirements, based upon the 25 kHz TDMA voice and data system described in Appendix H to the report on Agenda Item 5, as being pursued by the panel.

Appendix D

**Note 1, Capability to Maintain Radio Equipment, Section 3a(1)**

The current VHF and UHF transmitters and receivers currently utilized by the FAA were manufactured by the ITT Corporation (ITT) and have been operational at existing FAA communication facilities for over twenty five years. ITT has discontinued manufacture of these radio components and, as a result, some discrete components have become difficult to acquire. As obsolete parts fail (due to age, deterioration, and induced failures), the demand to re-engineer printed wire assemblies increases. Historically, re-engineering has cost the FAA FAALC \$40k to \$80k for each redesign and then \$1,800 for each unit produced.

As the ITT units age, failures are increasing thus increasing the demand for repair and supply services. The modular design of the ITT units was useful when facilities were staffed to perform repairs to the component level, but the staffing levels continue to decline within the FAA and the government. Additionally, the FAA work force in the GS-802 and 856 job series is aging, and even though these job series were excluded from the early retirement opportunity in April of 1994, within the next five years Airway Facilities could lose employees in these job series. With the emphasis on line replaceable unit (LRU) replacement at the site due to reduced staffing levels and policy initiatives, a disproportional increase in demand for service is felt at the depot support level.

Due to staffing level restrictions and the availability of commercial repair services for the ITT units, the FAALC has contracted for depot repair services rather than repair the units in house. At the time the Associate Administrator for the Aeronautical Center, AMC-1, requested AGCMP development, all ITT radio depot repair services were acquired commercially. Also, the FAALC was acquiring LRUs from the DOD through a primary inventory control activity (PICA) agreement. Two significant events impacting depot support of ITT units have occurred in FY94. FAA executive level decisions increased staffing levels at the FAALC to allow in house depot repair of items which had previously been repaired commercially. And the DOD successfully awarded a contract for redesign of printed wiring assemblies for the ITT units to vendor who has reverse engineered and produced units acceptable to the FAA. However, the government does not own redesign data rights; therefore, at the end of the DOD contract (five years) the requirement to procure these LRUs will be competed again putting the FAA at risk for depot support.

Appendix E

LIST OF ACRONYMS

AAF	FAA Airways Facilities, Headquarters
AAS	Advanced Automation System
AAT	FAA Air Traffic, Headquarters
ACF	Area Control Facility
AEEC	Airlines Electronic Engineering Committee
AF	Airways Facilities
AFSS	Automated Flight Service Station
AFZ	FAA Resource Management, Headquarters
A/G	Aircraft/Ground
AGCMP	A/G Communications Master Plan
AM	Amplitude Modulation
AMC	Associate Administrator for the Aeronautical Center
AMCP	Aeronautical Mobile Communications Panel
AM(R)S	Aeronautical Mobile Route Service
AND	FAA Communications, Navigation, Surveillance Systems, Headquarters
AOC	Aeronautical Operational Control
APOARC	Acquisition Review Council
ARA	FAA Acquisition and Safety Oversight, Headquarters
ARC	Acquisition Review Committee
ARTCC	Air Route Traffic Control Center
ASD	FAA System Architecture and Program Evaluation, Headquarters
ASE	FAA NAS System Engineering, Headquarters
ASR	FAA Office of Spectrum Policy and Regulations, Headquarters
AT	Air Traffic
ATA	Air Transport Association of America
ATC	Air Traffic Control
ATCT	Airport Traffic Control Tower
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
ATR	FAA Air Traffic Plans and Management, Headquarters
ATS	Air Traffic Services
BAA	Broad Agency Announcement
CBA	Cost/Benefit Analysis
CFR	Code of Federal Regulations
CFWG	Communications Functional Working Group
CNS	Communication, Navigation, Surveillance
CSMA	Carrier Sense Multiple Access

## Mission Needs Statement (MNS)

dB	Decibel
DOD	Department of Defense
DRMA	Distributed Reservation Multiple Access
DSBAM,	DSB-AM Double-Sideband Amplitude Modulation
E&R	Exchange and Repair
ELT	Emergency Locator Transmitter
EUR/RAN	European Region Air Navigation Meeting
F&E	Facilities and Equipment
FAA	Federal Aviation Administration
FAALC	FAA Logistics Center
FANS	Future Air Navigation System
FAR	Federal Aviation Regulation
FBI	Federal Bureau of Investigation
FCC	Federal Communications Commission
FDM	Frequency Division Multiplexing
FM	Frequency Modulation
FY	Fiscal Year
GA	General Aviation
HF	High Frequency
HW	Hardware
ICAO	International Civil Aviation Organization
ITT	ITT Corporation
ITU	International Telecommunications Union
JFK	John F. Kennedy Airport
K	Kilo, one thousand
KDP-1	Key Decision Point 1
KDP-2	Key Decision Point 2
kHz	Kilohertz
LCCB	Life Cycle Cost and Benefit
LRU	Line Replaceable Unit
MASPS	Minimum Aviation System Performance Standards
MHz	Megahertz
MNS	Mission Needs Statement
MOPS	Minimum Operational Performance Standard
ms	Milliseconds

## Mission Needs Statement (MNS)

MSA	Major System Acquisition
MTBF	Mean Time Between Failure
NAS	National Airspace System
NAVAID	Navigation Aid
NDI	Non-Development Item
nmi	Nautical mile(s)
O&M	Operation and Maintenance
ORD	Operational Requirement Document
PDC	Pre-Departure Clearance
PICA	Primary Inventory Control Activity
PIPREP	Pilot Report
PME	Prime Mission Equipment
PMO	Program Management Office
PTT	Push-to-Talk
R&D	Research and Development
RCAG	Remote Center A/G Communications
REC	Radio Control Equipment
RCO	Remote Communications Outlets
RF	Radio Frequency
RFI	Radio Frequency Interference
RIK	Replacement in Kind
RTCA	Radio Technical Commission for Aeronautics, RTCA., Inc.
RTR	Remote Transmitter/Receiver
SARP	Standard and Recommended Practice
SC-172	Special Committee 172
SRD	System Requirement Document
SW	Software
TDMA	Time Division Multiple Access
TDM	Time Division Multiplexing
TRACON	Terminal Radar Approach Control
TSARC	Transportation System Acquisition Review Council
UHF	Ultra High Frequency
VDL	VHF Digital Link
VHF	Very High Frequency